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MODELING AOB-NOB GROWTH RATE UNDER SPECIFIC OXYGEN STRATEGY FOR OPTIMIZATION SHORT-CUT NITROGEN REMOVAL PROCESS IN WWTPS

J. Drewnowski*,*, M.S. Shourjeh*, P. Kowal*, B. Szelag**, X. Lu*,***, L. Xie*****

* Gdansk University of Technology, Faculty of Civil and Environmental Engineering, Narutowicza 11/12, 80-233 Gdansk, Poland (E-mail: *jdrewnow@pg.edu.pl, przkowal@pg.edu.pl*)
** Kielce University of Technology, Faculty of Environmental Engineering , Av. Tysiąclecia Państwa Polskiego 7, 25-314 Kielce, Poland (E-mail: *bszelag@tu.kielce.pl)*
***Tongji University, Institute of Environmental Science and Engineering, 1239 Siping Road, Yangpu District, Shanghai 200092, China (E-mail: *luxi953@foxmail.com, sally.xieli@tongji.edu.cn*)

Introduction

The main objective in this paper is the modelling of nitrogen (N) removal technologies principles and operational factors which affect AOB (Ammonia-Oxidizing-Bacteria) and NOB (Nitrite-Oxidizing-Bacteria) kinetics in order to discover more cost-effective strategy in comparison with conventional N removal process in WWTPs. The most promising treatment compared to the conventional nitrification-denitrification (N-D), is deammonification (partial nitritation/anammox) process as well as is partial nitrification and denitrification process. It is based on the partial nitrification (nitritation) up to nitrite followed by the reduction of nitrite to N (denitritation). This process popularly known as short-cut N removal, reduces the aeration requirement by 25% and also the external carbon (C) source by 40% as compared to conventional nitrification-denitrification process, cutting down considerably the energy at WWTPs. Higher denitrification rate and lower wasted sludge production could also be obtained by this process. In the presence of low C/N ratio, and strong nitrogenous wastewater, N removal via AOB-NOB oxygen strategy showed promising results for the process optimization by mathematical modelling and computer simulations.

Due to the sequential oxidation property, the growth balance between AOB and NOB plays a key role in optimization of a nitrifying community. If AOB grows more quickly than NOB, and the ammonium oxidizing rate is higher than nitrite oxidizing rate, nitrite as an intermediate will be easily accumulated. Nitrite is toxic to aquatic ecosystems and poses potential threats to human health security. Furthermore, nitrite will be converted under anoxic condition by Nitrosomonas to nitrous oxide (N_2O), which is a lethal greenhouse gas (GHG) causing ozone depletion. Therefore, fully understanding the population and interaction of AOB and NOB in the nitrifying community is very important to optimize biological N removal. The aim of this paper was to develop and implement an cost-effective aeration process control for short-cut N removal by modelling AOB-NOB growth rate under specific oxygen strategy at WWTPs.

Materials and methods

The innovative technologies for N removal are based on the short-cut N removal pathways. The modelling of the kinetic parameters could attribute to better understanding of the impact of operational factors on the activities of AOBs, AnAOBs and NOBs and comparing the effect of various factors applied to the activated sludge system in order to optimize nitritation pathway and inhibit NOBs activities. The principle kinetic parameters within the Monod equation are the maximum specific growth rate of AOB ($\mu_{max,AOB}$) and NOB ($\mu_{max,NOB}$). Diverse parameters could influence the growth rate of AOBs and NOBs in model calibration for instance: the substrate concentrations, endogenous decay rate, temperature, DO and maximum specific growth rate. Moreover, the growth rate of AOBs are related to the concentration of ammonium in influent which could be followed by NOB repression process. Oxygen is known as a common substrate for both AOBs and NOBs, hence the affinity of AOBs and NOBs for oxygen are represented by half-saturation constants ($K_{O_2,AOB}$, $K_{O_2,NOB}$) as sensitive parameters in Monod equation. In the following, an Activated Sludge Model (ASM) based on Monod equations 1,2,3 for the growth rate of AOB and NOB is presented:

$$\mu_{AOB} = \mu_{max,AOB} * \left(\frac{S_{NH4}}{S_{NH4} + +K_{NH4}}\right) * \left(\frac{S_{O2}}{S_{O2} + K_{O2,AOB}}\right) - b_{AOB} \quad \text{(Eq. 1)}$$

$$\mu_{NOB} = \mu_{max,NOB} * \left(\frac{S_{NO_2^-}}{S_{NO_2^-} + K_{NO_2^-}}\right) * \left(\frac{S_{O2}}{S_{O2} + K_{O2,NOB}}\right) - b_{NOB} \quad \text{(Eq. 2)}$$

$$\mu_{AnAOB} = \mu_{max,AnAOB} * \left(\frac{S_{NH4}}{S_{NH4} + K_{NH4}}\right) * \left(\frac{S_{NO_2^-}}{S_{NO_2^-} + K_{NO_2^-}}\right) - b_{AnAOB} \quad \text{(Eq. 3)}$$

Where:

μ_{max}- maximum growth rate (d^{-1}); S_{NH4}, S_{NO2}, S_{O2}- concentration of ammonia (mg-N/L), nitrite (mg-N/L), DO (mg/L);
K_{NH4}, $K_{NO_2^-}$, K_{O2}- ammonia, nitrite half-saturation constant (mg-N/L), oxygen half-saturation (mg/L), b is the decay rate (d^{-1})

Organization of the modeling study procedure. The mathematical modelling and computer simulations could be carried out with the GPS-x simulation platform (Hydromantis, Canada). Furthermore, the effect of oxygen strategy on N removal efficiency could be estimated by performance of the whole plant model simulated by Mantis2, which is extended version of ASM.

Results

The future of the control systems in WWTPs belongs to smart process control systems. A core of the systems will be the simulation model implemented in the computer program (GPS-x, WEST) together with the appropriate algorithm for biochemical processes control depending on the current on-line measurements at the designated locations in the bioreactor. Currently, computer models of wastewater treatment processes are used as an auxiliary tool to forecast various technological variants and enable searching for optimal solutions, i.a. in the field of aeration costs. The proper aeration strategy could be successful in inhibiting the activity of NOB organisms compared with AOB to avoid accumulation of NO_3-N in the effluent. Moreover, an application of an appropriately selected aeration strategy could reduce energy consumption and did not affect the efficiency of biological wastewater treatment, even could increase the N removal process effectiveness.

Nowadays, the most important objective of the cost-effective WWTPs is to invent efficient and sufficient AOB-NOB control strategies. The results identified the following issues: removing the NOB bacteria from the system, growing and keeping the AOB bacteria in the system. Theoretically, the numerical ratio of AOB to NOB in a balanced nitrifying system should be 2:1 according to thermodynamics and electron-acceptor transfer which means that AOB should be the dominant bacteria in a nitrifying community. However, a disproportion in the ratios of AOB/NOB existed, from time to time, in floc and/or granular sludge as well as lab/pilot/full-scale experiments. In the lab/pilot tests of Mari et al. (2012), an elevated NOB/AOB ratio (3.0–4.0) was observed in an aerobic granular sludge. Ramdhani et al. (2013) investigated the nitrifying bacteria communities at two full-scale domestic WWTPs in South Africa: lower AOB/NOB ratios were detected, 1.0–1.5 in Kingsburgh WWTP and 0.8–1.0 in Darville WWTP. It suggest, that more investigation are needed in order to find the best growth rate balance between AOB/NOB using specific oxygen strategy enhance with mathematical model and computer simulations, which will be the task of this study.

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CONTAMINATION OF SURFACE WATERS BY HEALTH AFFECTING ENDOCRINE ACTIVE COMPOUNDS

Sylwia Duda-Saternus*, Iwona Bojar*, Grzegorz Łagód**

** Institute of Rural Health in Lublin, Department of Woman Health. Jaczewskiego 2, 20-090 Lublin, Poland, e-mail: sylwia.m.duda@gmail.com; bojar.iwona@imw.lublin.pl*

*** Lublin University of Technology, Faculty of Environmental Engineering, Nadbystrzycka 40B, 20-618 Lublin, Polska, e-mail: g.lagod@pollub.pl*

Currently, trace pollution, associated with the development of civilization and human activity, becomes increasingly prevalent in the natural environment. These are impurities such as: active pharmaceutical compounds – PhACs, residues of products used for personal hygiene (PCPs), artificial sweeteners – ASs, or endocrine active compounds, which can affect the functioning of endocrined chemicals in the body (EDCs). These compounds are biologically active and persistent as well as accumulated in the environment. As a result, the undesirable ecological phenomena caused by the said pollution, but also their strong impact on human health are being increasingly discussed.